THE NATIONAL BUREAU OF STANDARDS / JUNE 1973

Technical News Bulletin

Postal Automation Commemorated

See page 131

NBSTAR 57(6) 129-152 (1973)
A publication of the U.S. Department of Commerce

NATIONAL BUREAU OF STANDARDS

Technical News Bulletin

JUNE 1973 / VOL. 57, NO. 6 / ISSUED MONTHLY

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Nat. Bur. Stand. (U.S.) Tech. News Bull.
CODEN:NBSTAR 57 (6) 129-152 (1973)

Superintendent of Documents Catalog No. C13.13:57/6

Library of Congress Catalog No. 25-26527

Cover: Postmaster General E. T. Klassen has announced the design of a set of 10 postage stamps that honor the Nation's postal employees. The 8-cent stamps depict services performed by postal people, ranging from the sale of stamps in a post office to the processing and delivering of mail. See page 131 for an article on NBS involvement in postal automation. Photo of letter sorter courtesy of Robert Hurwitz.

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The National Bureau of Standards serves as a focal point in the Federal Government for assursuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized as follows:

The Institute for Basic Standards

The Institute for Materials Research

The Institute for Applied Technology

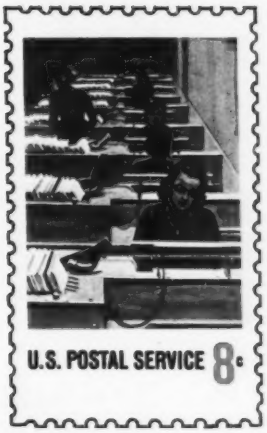
The Institute for Computer Sciences and Technology

Center for Radiation Research

Center for Building Technology

The TECHNICAL NEWS BULLETIN is published to keep science and industry informed regarding the technical programs, accomplishments, and activities of NBS.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Annual subscription: Domestic, $6.50, foreign, $8.25, single copy, 65 cents. The Secretary of Commerce has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through June 30, 1976.



Postal Automation Commemorated

MAN AND MACHINE COSTAR on 10 new stamps issued April 30 in celebration of Postal Week, April 29-May 5.

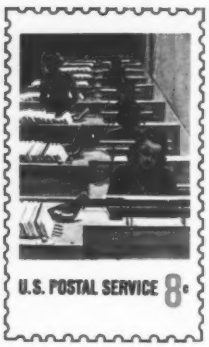
Shown in the series are typical operations, old and new, used by some 700,000 postal workers to move almost 90 billion pieces of mail a year. A highlight of these operations, depicted on one of the stamps, is automatic letter-sorting machinery that can sort more than a million letters a day—designed in the 1950's by Jacob Rabinow and his Rabinow Engineering Co., under contract to NBS.

Rabinow recently rejoined the Bureau and, as Chief Research Engineer, is now heading the Center for Consumer Product Safety and providing guidance to the new Experimental Technology Incentive Program.

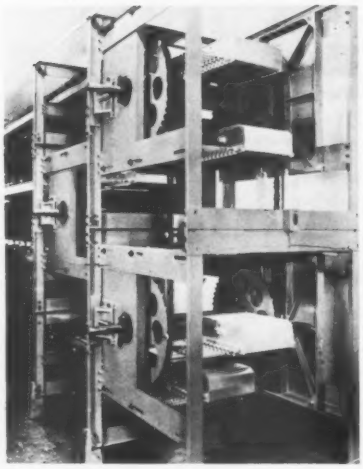
Jacob Rabinow is an inventor of long standing. Among his contributions are the magnetic fluid clutch and devices used in ordnance, sound reproduction, clocks and watches, electronics, and computers.

turn page

POSTAL *continued*

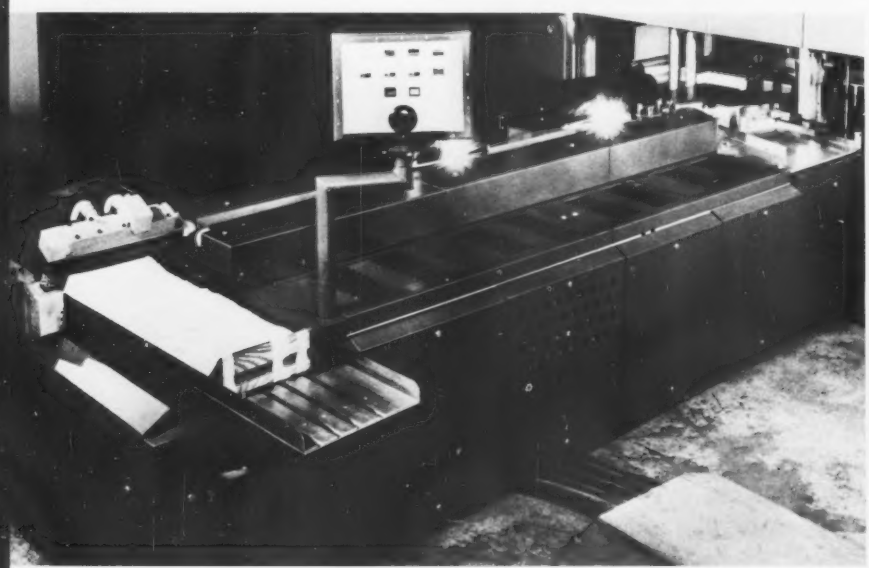


First model of a letter-coding station built by Rabinow Engineering Co. under contract to NBS. NBS designed the "extractor" codes for these experiments.



View of a section of the letter-sorting machine.

A Zip-code reader was also built for the Postal Service by Rabinow Engineering Co. This optical-character-recognition (OCR) machine is an outgrowth of the OCR work done at NBS by Jacob Rabinow in the early fifties.



The Bureau's involvement in postal automation began in the early fifties with a joint presentation delivered at an Advancement of Management Society meeting in Washington by Rabinow and Samuel Alexander, then NBS Computer Division Chief. Rabinow demonstrated a punched-card sorter he had developed for the Census Bureau and a model of his magnetic disc memory, designed for the Army's Aberdeen Proving Grounds. Devices like these, linked to computers, could conceivably be used for the sorting of mail, Rabinow told the group.

Rabinow claimed that there were aspects of the huge postal operation that could be successfully automated. A former postmaster general expressed skepticism because "every letter was different." This would, in his view, thwart efforts at automation.

Meetings with Post Office officials, Congressmen, and Budget Bureau experts resulted from Rabinow's challenging remarks. Meanwhile Rabinow left the Bureau in February 1954 to form his own company. About a year later, the

Jacob Rabinow is shown with his first model of the letter sorter and a photo of a Postal Service letter sorter in action. Photo courtesy of Consolidated News Pictures.

Postal Service asked NBS to do some preliminary design work on automatic letter sorting. The Bureau accepted the contract and gave Rabinow Engineering a subcontract to do the actual machinery development, with NBS personnel acting as monitors. Israel Rotkin served as NBS project manager. The Bureau's Computer Division was active in monitoring the work and doing systems studies and related research and development for the Postal Service.

Rabinow Engineering, under contract to NBS, developed a letter sorter, special memory devices, optical and magnetic envelope coders, and special equipment for coding abbreviated addresses onto envelopes for subsequent machine processing. Further contributions by the company included computer equipment to be used in conjunction with letter-sorting machines to read and sort coded mail.

The working principle of the letter-sorting machine is essentially this: Letters are presented automatically one by one to each operator. The operator reads the address, decides into which bin the letter should go, and presses a set of keys with the desired number. The letter leaves the operator and is automatically inserted into a pocket of a moving belt conveyor. Each pocket is accompanied by a "shish kebab" coding device consisting of a shaft with 13 wheels. Each wheel can have one of two positions—a zero position and a one position. Thirteen wheels can produce over 8,000 different combinations, or 2 to the 13th power.

As the operator presses the key, the information is transferred to a relay memory, a letter is dropped onto a conveyor belt and the appropriate dial is set for the desired destination. The coding device's wheels travel on tracks and upon reaching the correct point in their travels fall into grooves matching their position. This trips a door in the bottom of the conveyor pocket and the letter falls into a station or receptacle from which it is removed by hand later.

The wheels are reset to the zero position on the return trip to the operating stations and are set again when the next letter is dropped into the same pocket. Normally, only nine wheels are needed to sort into 300 pockets. The additional wheels are used for automatic change of stations when needed and are also used when the sorting machine is controlled by OCR (optical character recognition) or other automatic means.

Each operator normally can control 50 to 60 letters per minute into 100 to 276 sorts—compared with the old manual sorting of 20 letters per minute into some 60 destinations. Each of the manual letter sorters now being built employs 12 operators. In some of the latest experimental installations, very sophisticated OCR machines can be used with two sorting machines. Together, they sort 24 letters per second. Rabinow Engineering eventually built a machine that sorts letters into a thousand categories.

Parallel with the development of the mail-sorting machine, NBS also developed various code-extraction schemes to be used in unison with the sorter.

Eventually, the Postal Service itself took over the monitoring of this research and development effort and placed large orders with other companies for the building of letter-sorting machines. There are now several hundred in use at large post offices throughout the United States.

One of the first OCR machines, designed by Rabinow during his earlier employment at the Bureau and demonstrated in 1954, is now on permanent display at the Smithsonian Institution in Washington, D.C.

NBS Analyzes Human Factors in Post Office Operations

While NBS engineers and computer experts contribute to the progressive automation of the U.S. postal system, psychologists on the Bureau's staff conduct important research on the human factors that affect postal operations.

Where, for example, are the potentially hazardous spots for operators, maintenance men, and crew supervisors involved in the handling and sorting of mail sacks by means of large and complex machines? What about the feasibility or infeasibility of using a recorded human voice to instruct an electronic memory controlling a sorting machine? Are armrests helpful to operators using keyboards? What kind of work-rest cycles contribute to optimum performance by operators of multiposition letter-sorting machine consoles? These are typical problems tackled on behalf of the postal service by NBS human-factors analysts.

NBS SEEKING "CHILD-PROOF" MATCHES

To encourage the match industry to make safer products, NBS along with the Bureau of Product Safety (BPS), Department of Health, Education, and Welfare, is presenting proposals to the industry requesting (1) immediate adoption of standards similar to those recently certified by Canada, and (2) development of safety matches that are "child-proof."

These plans were revealed by Dr. Joseph E. Clark, Acting Chief, Fire Technology Division, in a recent letter responding to an inquiry from Senator Warren G. Magnuson, Chairman of the Senate Committee on Commerce.

An NBS study[1] indicates that children are among those most frequently involved in fires started by matches. The report recommends the education of parents concerning risks and the redesign of matches (and lighters) to make them harder for children to light.

NBS had commissioned Trident Engineering Associates, Inc. to develop design modifications for book matches and for cigarette lighters.[2] In all, 15 modifications were proposed and rated for safety.

Among the suggested designs were:

·A matchbook with a sleeved striker, requiring the insertion of a thin match and coordinated action by both hands.

·Matches that require two actions within 4 or 5 seconds.

·One that would limit burning time to about 4 or 5 seconds and will die out when dropped.

One or more of the suggested designs, if adopted, would lead to increased safety for the entire population.

A letter was sent to the industry by BPS Director Malcolm Jensen requesting their taking the initiative in developing safer matches, with replies requested by mid-March. Meetings of BPS, NBS, and industry representatives are being planned to develop reasonable requirements for matches similar to those in the Canadian Standard as a first step and to develop requirements for "child proof" matches as a long-range, but not-too-distant, goal.

Under Canada's new safety regulations, matches with weak stems or splints that require a compressive action for striking and matches that drop glowing particles or explode have now been banned. Among the Canadian requirements are the following:

(1) Matches must be difficult to ignite accidentally; with covers that enclose matches completely.

(2) The staple holding the match cover to the base of the match cluster must not interfere with the striker's grip.

(3) All book matches sold in Canada will have the striker strip on the back rather than on the front of the cover. (Effective January 1, 1974.)

(4) Ignition compounds must be uniformly applied to match tips. The tips must not be chipped, split, cracked, crumbled, or be stuck to the tip of another match.

(5) After a match flame has been extinguished, the splint of the match must not have an afterglow that lasts longer than 3 seconds.

Most fires involving children playing with matches are caused by the child striking the match and then dropping it onto his clothing. A "child-proof" match, therefore, would be one that is difficult, if not impossible for a child of less than 5 to light; and if struck, would extinguish, instead of starting a fire, when dropped.

Because studies show that children under 5 cannot perform two successive acts in less than 5 seconds, a design requiring two such motions might render a match "child-proof": e.g., a match that must be activated and then struck within 5 seconds. Another approach under consideration is "child-proof" match containers similar to—but more effective than—"child-proof" pill bottles.

If good standards can be developed by these voluntary procedures, they will be submitted to the new Consumer Product Safety Commission for approval as mandatory standards.

[1] Slater, J. A., Buchbinder, B., and Tovey, H., Matches and Lighters in Flammable Fabric Incidents: The Magnitude of the Problem, Nat. Bur. Stand. (U.S.), Tech. Note 750 (Dec. 1972).

[2] Design Concepts for Safer Matches and Lighters, Trident Engineering Associates, Inc., Annapolis, Md. (Sept. 29, 1972).

Failed parts found in aircraft engine removed from service on the basis of oil analysis.

A U.S. Navy Phantom II jet, one of the many aircraft kept flying using "SOAP."

SRM BENEFITS IN "SOAP" FAR EXCEED COSTS

Benefits from standard reference materials (SRM's) can be great.

The Air Force estimates that their Spectrochemical Oil Analysis Program (SOAP) saves $13 million to $50 million annually and saves countless air crew lives.

In the SOAP program, engine wear is monitored by removing and analyzing a sampling of lubricating oil for metal content. When a significant increase in metal content is detected, the engine is scheduled for repair.

The NBS contribution has been the certification and issuance of SRM's which allow close quality control of the measurement process. By one estimate the SRM portion of the SOAP program, conducted by the Office of Standard Reference Materials under the direction of J. P. Cali, annually saves American industry and Government 24 times the cost of developing the materials at NBS.

This early warning system was developed by the railroads. And, in order to insure the technique's reliability, railroad and petroleum company officials came to NBS for help. In 1960, NBS provided a series of 24 oil-soluble, metallo-organic compounds for use as SRM's to calibrate the spectrometers used in analytical laboratories.

In addition to the Air Force and the railroads, the Navy is an enthusiastic user of the technique. At Pensacola Naval Station alone, about 2,500 samples are analyzed daily.

Ship safety signals such as those pictured on this old lighthouse are being replaced by less costly – and also less pleasant sounding – electronic devices.

NBS AND THE RETURN OF THE MUSICAL FOGHORN

Do you remember the BEE-OHH sound of foghorns? That's rapidly becoming a sound of the past. Those richly harmonic air horns are being replaced by less costly—and also less pleasant sounding—electronic acoustic horns. And a rising tide of complaints from on-shore residents has led the Coast Guard to consult with psychophysicists at the Bureau.

In a first-of-its-kind exploratory project which marries a new theory with practical problem-solving, the Sound Section of the Institute for Basic Standards recently completed a pilot study of sounds that people like and dislike for the U.S. Coast Guard's Ocean Engineering Division.[1] Results of these and of other studies directed by Dr. John A. Molino might also contribute to the redesign of police, fire, and disaster warning signals so that they are more pleasant to the ear while still delivering their warning. The studies may also pave the way toward a sound-measuring method that will resolve a debate among adherents of some 17 possible noise survey procedures.[2] This, in turn, would affect the production of millions of dollars worth of sound level meters

used at airports and in industry for occupational safety.

Modern electric sound generators used in acoustic navigation aids produce a relatively pure-tone signal, Molino explains. Thus, the NBS study sought to ascertain the following:

°What are people's preferences among four pure-tone signals?

°At what level would each tone become aversive?

°Would any combination of tones be preferable to single pure tones?

°At what level would these composites become aversive?

The study set out to measure a jury's preference for and its aversion to tones and composites. Though the laws of consonance and dissonance say that three of the four pure tones studied should combine very well, there was little empirical data to prove it.

The NBS jury preferred the higher frequency pure tones and composites, and also found them less aversive at higher sensation levels. The results suggest that the Coast Guard steer toward the higher frequencies tested, and add pure tones for better composites when lower tones are used.

The new procedure used in the aversiveness portion of the study was arranged to avoid discrepancies caused by verbal descriptors (such as "loud," "noisy," "unacceptable," "unpleasant," etc.). Intense noise, without instructions regarding noise qualities, was used as an aversive stimulus to find out how hard a person would work to get away from it. Ten college students took turns in the sound booth for 1 hour at a time, reading a book on English grammar—a task which models an everyday activity. As the sound increased, the student could press a telegraph key to reduce sound intensity, if he so desired. In this way the aversive properties of a stimulus—those which one would work to get away from—are measured operationally. This is one of a series of sound studies based on that novel procedure.[3]

[1] Molino, J. A., Zerdy, G. A., and Frome, F. S., Toward a more musical foghorn. Submitted to the Journal of Applied Psychology, American Psychological Association, Washington, D.C.

[2] Szecosdy, A. J., The state of the art in noise surveys, Journal of the Audio Engineering Society **20**, No. 7, p. 574 (1972).

[3] Molino, J. A., The psychophysical side of sound, Nat. Bur. Stand. (U.S.), Tech. News Bull. **54**, No. 9, p. 195 (1970).

Proceedings of the 5th Temperature Symposium Published

The 5th Symposium on Temperature was held during June 1971 in Washington, D.C., under the auspices of NBS, the American Institute of Physics, and the Instrument Society of America. The Symposium proceedings are entitled *Temperature, Its Measurement and Control in Science and Industry, Volume 4*, and have just recently become available from the publisher: the Instrument Society of America.

The Symposium covered progress in thermometry research, its application and instrumentation during the last decade. The contributors of papers, which were over 200 in number, represented many international laboratories and covered a large variety of thermometric endeavors. For convenience, Volume 4 of *Temperature, Its Measurement and Control in Science and Industry* is published in three parts; the volume provides in-depth coverage of the following specific areas:

1. Temperature Scales and Fixed Points
2. Radiation Thermometry
3. Omnibus Thermometry
4. Resistance and Electronic Thermometry
5. Magnetic and Quantum Electronic Thermometry
6. Temperature Control and Calibration
7. Bridges and Potentiometric Methods for Temperature Measurement
8. Thermoelectric Thermometry
9. Biology and Medicine
10. Geophysical and Astrophysical Temperature Measurements.

Symposia on Temperature have been held approximately each decade for the last 50 years. Their Proceedings contain compilations of thermometric knowledge, experience, techniques, and applications that have been invaluable in years past. The latest Proceedings concentrate on the definition of the International Practical Temperature Scale of 1968* (one of the most significant developments in recent decades), and cover techniques of measurement that extend from the lowest temperatures that are reasonably attainable up to astrophysical temperature determinations. The papers are sufficiently numerous that it is impractical to list their titles in this notice. However, it is expected that Volume 4 will be received as a desirable updating of the preceding volumes of *Temperature, Its Measurement and Control in Science and Industry.*

Each of the three parts of Volume 4 may be purchased for $40. Or the entire three-part Volume may be ordered for $110. (Pennsylvania residents only, add 6 percent sales tax.) Inquiries and orders should be addressed to the publisher:

The Instrument Society of America
400 Stanwix Street
Pittsburgh, Pa. 15222

* The text in French of this scale is published in Comptes rendus de la Treiziéme Conference Générale des Poids et Mesures, 1967-1968, Annexe 2, and Comté Consultatif de Thermométrie, 8e Session, 1967, Annexe 18. The text in English is published in Metrologia **5**, No. 2, p. 35 (Apr. 1969).

NBS POLICY FOR USAGE OF SI UNITS

Readers of the NBS Technical News Bulletin have followed with interest the Bureau's policy toward, and usage of, the International System of Units (SI). For this reason a recent policy statement on this matter, issued for the guidance of the NBS staff, may have some general interest. It appears below.

The International System of Units (SI)[1] was defined and given official status by the General Conference of Weights and Measures in 1960. NBS adopted the SI for use by its staff in 1964,[2] and issued statements interpreting this policy in 1968[3] and 1971.[4] While the basic policy remains unchanged, its restatement below may be useful at this time. This discussion references NBS Special Publication 330, 1972 Edition,[1] for SI units and units that may be used with SI rather than listing them.

It is the policy of the Bureau to support the International System of Units (SI) and encourage its adoption. During a transition period, exceptions to the SI are allowed in the interests of effective communication with the expected audiences for Bureau technical writings. These exceptions are permitted only during the transition period; they are not to be used as a basis for perpetuating non-SI usages.

Numerical data are used in NBS publications in two distinct ways: as descriptive data and as essential data. NBS policy for the transition period accepts different treatment of these two classes of data, although they may be presented in the same text; each may cite appropriate units.

Descriptive data describe arrangements, environments, noncritical dimensions and shapes of apparatus, and similar measurements not entering into calculations or expression of results.

Essential data express, lead up to, or help to interpret the quantitative results of the activity that is being reported.

DESCRIPTIVE DATA

Descriptive data should be expressed in the most useful and convenient manner. Translation into SI is not required. The units best understood by the intended audience are the most appropriate. Where non-SI units are used, the author is encouraged to add SI equivalents in parentheses but usage within a paper should be consistent on this point. Commerical gauge designations or other standard nomenclatures, e.g., drill sizes, are acceptable. As SI units become more commonly used for commercial products, use of SI units in descriptive data should conform.

ESSENTIAL DATA

The transition period to general usage of SI units is expected to be dependent on the field of science or technology and on the particular unit itself. In those fields in which use of SI units would create a serious impediment to communication, the essential data may be expressed in the units customarily used in the relevant field of technology. SI equivalents should be added in parentheses, or in parallel columns in tables. If graphs are used as the primary or sole means of presenting essential data, the coordinates may be divided according to customary usage, but a secondary set of coordinate markings in SI units should be included. The top and right-hand side of the graph are often appropriate for this purpose. If graphs are used only to indicate trends, or as supplements to tables, units customary in the field are acceptable without SI translation. NBS authors should, however, use the SI as soon as the level of SI usage in the related field renders it an efficient communication device. Familiarity with SI units is recommended to all NBS staff.

Essential data shall be expressed in SI units, or in units approved by the International Committee of Weights and Measures (CIPM) for use with the SI (Tables 1-9 of NBS Special Publication 330). Values in other units may be added, in parentheses, where it is felt that this information will improve the communication between authors and readers.

The CIPM has authorized, for a limited time, the use of the following common units with the SI:

nautical mile	bar
knot	standard atmosphere
ångström	gal
are	curie
hectare	röntgen
barn	rad

Centimeter-Gram-Second (CGS) units with special names should not be used with SI units; use of the fol-

lowing units should be avoided (except, of course, during the transition period):

erg	oersted
dyne	maxwell
poise*	stilb
stokes*	phot
gauss	

The CIPM has deprecated the use of the following names:

- fermi (use femtometre)
- metric carat
- torr
- kilogram-force
- calorie
- micron (use micrometre)
- X unit
- stere
- gamma (use nanotesla)
- gamma (use microgram)
- lambda (use microliter)

Reference data used generally in science and technology should be expressed in SI units with appropriate indication of conversion factors into traditional units or with parallel columns of converted values. Standard reference data applicable primarily to scientific interests (e.g., tables of X-ray atomic energy levels) should be expressed in SI units. Non-SI units may be included as parallel entries.

Where the general usage in any field does not recognize SI units, NBS authors should employ units comprehensible to their readers, but should try to increase reader familiarity with SI units as rapidly as possible. Again, the device of parallel columns (familiar plus SI units) is recommended.

In the lists given in NBS SP-330 (e.g., Table 3), the short names for compound units, such as "coulomb" for "ampere-second," exist for convenience, and their use is not compulsory. For example, communication sometimes benefits if the author expresses magnetic flux in volt-seconds, instead of using the synonym webers, because of the descriptive value implicit in the former unit phrase.

The analysis, interpretation, or application of essential data may involve angles and the relative values of natural functions (sine, tangent, log sin, etc.). In these cases, the angles may be expressed in degrees rather than in radians.

*The transition period for adoption of SI units instead of these CGS units is expected to be longer than for the other units in this list.

NATURAL UNITS

In some cases, it is convenient to express quantities in terms of fundamental Lorentz invariant constants of nature. This situation arises in theoretical work; experimental data are rarely determined directly in terms of these constants. The use of these constants as "natural units" is acceptable. The author, however, should state clearly which natural units are being used; such broad terms as "atomic units" should be avoided when there is danger of confusion.

Typical examples of natural units are:

Unit	Symbol
elementary charge	e
electron mass	m_e
proton mass	m_p
Bohr radius	a_0
electron radius	r_e
Compton wavelength of electron	λ_C
Bohr magneton	μ_B
nuclear magneton	μ_N
velocity of light	c
Planck's constant	h or $\hbar$

SPECIAL CONSIDERATIONS

1. It is acceptable to use the Celsius temperature (symbol t) defined by the equation

$$t = T - T_0$$

where T is the thermodynamic temperature, expressed in kelvins, and $T_0 = 273.15$ K by definition. The Celsius temperature is in general expressed in degrees Celsius (symbol °C). The unit "degree Celsius" is thus equal to the unit "kelvin," and an interval or a difference of Celsius temperature may also be expressed in degrees Celsius.

2. In situations where the use of the symbol K for thermodynamic temperature would lead to confusion with other symbols, it may be replaced by °K.

3. Logarithmic measures such as pH, dB, and Np are acceptable.

4. On recommendation of the CIPM, the names of multiples and submultiples of the kilogram are formed by adding prefixes to the word gram.

5. Words and symbols should NOT be mixed; if mathematical operations are indicated, only symbols should be used. For example, one may write "joules per mole," "J/mol," "J mol^{-1}," but not "joules/mole," "joules mol^{-1}," etc.

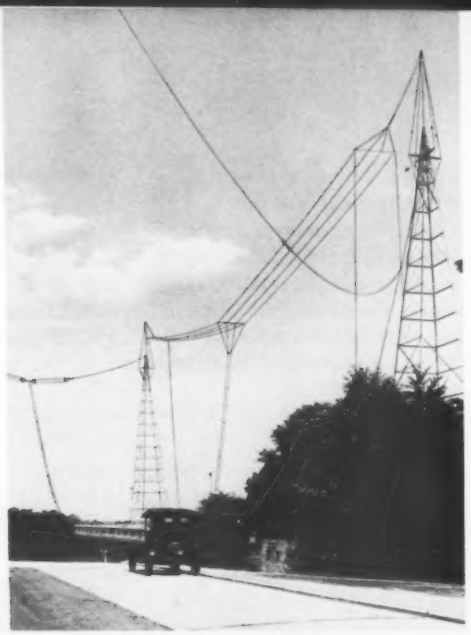
6. In keeping with the recommendations of various international bodies and domestic professional societies, NBS encourages the use of the spelling "metre" in communications whose principal audience is the technical community. This would include students receiving technical training at the college level. However, in order to minimize possible resistance to the use of the metric system by nontechnical groups due to introduction of an unfamiliar spelling, NBS communications addressed to such audiences (including students through high school) should use the spelling "meter." Uniform international spelling of the word "litre" is of less significance than "metre" since "litre" is not a base unit of SI, and the staff is encouraged to continue using the spelling "liter." Both spellings for both words are considered to be acceptable.

[1] A complete description of SI, together with guidelines for its implementation established by the International Committee of Weights and Measures, appears in the International System of Units, translated by C. H. Page and P. Vigoureux, NBS Spec. Pub. 330, 1972 Edition.

[2] NBS Adopts International System of Units, Nat. Bur. Stand. (U.S.), Tech. News Bull. **48**, No. 4, p. 61 (1964).

[3] NBS Interprets Policy on SI Units, Nat. Bur. Stand. (U.S.), Tech. News Bull. **52**, No. 6, p. 121 (1968).

[4] Policy for NBS Usage of SI Units, Nat. Bur. Stand. (U.S.) Tech. News Bull. **53**, No. 1, p. 18 (1971).



This photograph, taken 50 years ago, shows the original transmitting antenna towers used by WWV in Washington, D.C. The short antenna on the left was used for "shortwaves" while the antenna on the right was used for "the longer waves of their standard wave transmissions."

Golden

From the top of a 400-ft. transmission tower at the Fort Collins site a portion of the WWV and WWVB-WWVL facilities can be seen. On the left is the WWVB-WWVL building and on the right the WWV building. A total of 380 acres encompass the facilities.

The original WWV transmitter was described in a 1924 magazine as a "1-kW continuous-wave set of the master-oscillator power-amplifier type especially designed to operate over a wide range of frequencies and to permit rapid change from one frequency to another." This photo was taken in 1923 at the NBS Washington, D.C. facility.

On March 6, 1923, NBS started regularly scheduled broadcasts. The broadcasts originated from WWV, a laboratory radio station located in the NBS radio building on Connecticut Avenue in Washington, D.C. The broadcasts brought order to a burgeoning radio industry that was threatening to strangle on self interference.

WWV AIDES PIONEER RADIO

The early WWV broadcasts were appreciated from their start. This was typically expressed in a QST Magazine editorial, October 1924:

"Probably no radio station has ever rendered the American radio world so great a service as that of WWV in transmitting the standard wave signals. Before these signals began, both broadcasting and amateur waves were uncertain and often wavemeters disagreed violently. Since the signals began, those in the East have been able to make precision calibrations of their own wavemeters and pass the information on into the West."

The QST editorial was a sincere expression of appreciation from a troubled industry. Radio was the

For 50 years, one of the country's most popular radio stations has been WWV. In spite of its sustained listenership, the station has no music, no commercials, and almost no talking. Its program consists of ticks, beeps, brief voice announcements, and frequency signals.

Anniversary of WWV

glamour industry of the age. Proliferation of commercial and amateur broadcasting stations was exponential. Regulation was minimal. For sheer lack of dependable standard frequencies, broadcasters were unable to calibrate their equipment and stay within their assigned frequencies. The result was static, garbling, and fading, a phenomenon which results from interfering radio waves cancelling each other. Thus, a fledgling industry was threatened with self-annihilation even before becoming firmly established. No wonder it welcomed the 1923 standard-frequency broadcasts of WWV as the greatest service to American radio and promptly embarked on a self-policing action using WWV standards!

NOW AND THEN

Today, on the golden anniversary of its first regularly-scheduled broadcasts, WWV occupies a 380-acre site near Fort Collins, Colo., with its own building, emergency power plant, and antenna field. It continues to broadcast standard frequencies. Fifty years ago, the standard frequencies helped the broadcasting industry transmit primitive "radio telephony" to a select few with bulky receivers. Today, WWV serves a mature and well-ordered broadcast industry reaching virtually every home in America with video and sound.

The original WWV transmitter broadcast a number of standard frequencies from 200 to 545 kilocycles per second (kilohertz) with an accuracy of 1 part in 10,000 and transmitter power of 1 kilowatt. Today's WWV broadcasts range from 100 cycles per second (hertz) to 25 million cycles per second (megahertz), with an accuracy of a few parts in 10,000 billion and up to 10 kilowatts transmitter power.

Original broadcasts were made between 11 p.m. and 1:15 a.m. eastern standard time, after commercial stations left the air. This guaranteed no interference, which was the principal problem of the radio industry during that era, and allowed users a chance to calibrate their wavemeters. Today, WWV broadcasts around the clock.

Early WWV broadcasts, with accuracy controlled by a wavemeter, were more-or-less dependably received east of the Mississippi, and were reported to have been heard as far away as England and Italy. Today, WWV broadcasts reach throughout the world. The Pacific Ocean area is supplemented by a sister station, WWVH on the Hawaiian Island of Kauai, which NBS added to its broadcasting system in 1948.

TODAY'S SERVICES

In addition to providing services which parallel the original WWV broadcasts (standard frequencies), WWV now provides audio tones of 440 and 600 hertz for the musical and electrical industries respectively; 1-second time ticks; time-of-day voice announcements; time corrections to maintain proper earth-atomic time relationships; official announcements of the Federal Government; radio-propagation forecasts; geophysical alerts and summaries of selected geophysical events during the past 24-hour period; weather information for the Atlantic area; and time of the year information in minutes, hours, and days.

turn page

FIVE SITES IN 50 YEARS

WWV standard broadcasts came from the NBS grounds in Washington, D.C., for nearly 8 years; until January 1931, when frequency transmissions began from a new location in College Park, Md., northeast of Washington.

After 2 years at College Park, the transmitter was moved to a 25-acre site at the Experimental Farm of the Department of Agriculture in Beltsville, Md., northeast of Washington, D.C. January 1943 was moving time again for WWV, this time to a site 3 miles south, but still with a Beltsville address.

There in its new facility, WWV served the nation with time and frequency broadcasts during the critical years of World War II. Many a veteran navigator of an airplane or ocean vessel nostalgically recalls the welcome sound of the monotonous format of WWV broadcasts which helped him guide his vessel through the trackless and hostile foreign territories. It was a reassuring sound emanating from a small brick building at Beltsville with blackout curtains covering the windows. The wavemeter standard had long since been replaced by the tuning fork and the tuning fork had now been replaced by three quartz crystals buried in a concrete vault 25 feet below the surface of the ground. There temperature and humidity were constant and the crystals provided time and frequency signals of unprecedented accuracy.

In the late 1950's, the growing city of Greenbelt encroached on Beltsville and the address of the WWV site was changed to Greenbelt. NASA's Greenbelt Space Center was crowding WWV and finally became owner of the site. The equipment was obsolete and the location was far from the new NBS time and frequency control center, the Radio Standards Physics Division at Boulder, Colo. A new site was selected for WWV about 7 miles north of Fort Collins, Colo., (50 miles from Boulder) where there was no industrial crowding and the highly conductive soil of an ancient lake bed provided an ideal transmitting site. In addition, this central location provides more uniform coverage of the continental United States.

Transmissions from the Fort Collins site began at 5 p.m., December 1, 1966 (zero hours Greenwich time). Transmission from the new site brought an immediate and dramatic increase in accuracy; for though the atomic clock in Boulder had become the primary standard of frequency and time for NBS in 1957, the new station at Fort Collins was first to have commercial cesium oscillators at the transmitter site. This addition allowed daily comparisons with the atomic clock.

1940 FIRE STOPS WWV FOR 5 DAYS

Throughout its history, WWV scheduled broadcasts have only rarely been interrupted. One interruption occurred on November 6, 1940, when a fire broke out at the (Beltsville) station and almost entirely destroyed it. However, frequency generating equipment was salvaged from the basement of the burned building. An adjacent building, not damaged by the fire, contained a small transmitter. By coupling the two, NBS engineers had WWV back on the air November 11 with no loss of accuracy, although announcements were temporarily made by Morse code.

"By keeping in touch with users, NBS has kept WWV broadcasts relevant to their needs," Peter P. Viezbicke, Section Chief for frequency broadcast services within the NBS Time and Frequency Division related. For instance, the most used service of WWV is time-of-day information. This need holds true not only for navigators, but also for transportation, telephone and broadcasting companies, radio amateurs, and just plain people who want to know the proper time of day. In response to time-of-day demands, WWV now broadcasts Greenwich time voice announcements once each minute. A simple conversion for listeners in every time zone gives each his proper time. Those without shortwave receivers can call by telephone (303/499-7111) and hear the broadcast any time, day or night. Approximately one-half million calls per year are received.

USERS "TUNE-IN" WWV

Major users tune their receivers to one of six standard carrier frequencies: 2.5, 5, 10, 15, 20, or 25 megahertz. Identical information is simultaneously broadcast on each frequency. Accurate time and frequency information users include spacecraft-tracking stations, civilian and military aircraft and ships, commercial radio and television broadcasters, seismographers, geologists, astronomers, electric-power distributors, manufacturers of musical instruments, and scientific laboratories. In fact, almost all time references within the United States can ultimately be traced to WWV services.

WWV'S FUTURE

Will WWV survive another 50 years? Who knows?

"The National Bureau of Standards is currently engaged in perfecting alternate forms of dissemination which might make standard shortwave broadcasts obsolete," says James A. Barnes. Barnes is Chief of the NBS Time and Frequency Division. Until alternate methods are perfected, John Stanley, WWV's Chief Engineer, and his dedicated crew at the Fort Collins site will continue the service which has survived 50 years of wars, depressions, moves, and fire.

ONGOING
MAGNETOHYDRODYNAMIC (MHD)
MATERIALS RESEARCH

A major materials program for magnetohydrodynamic (MHD) power generation is underway at the Bureau under sponsorship of the Department of Interior's Office of Coal Research. Materials and conditions that could be used to create a more efficient, longer-lasting MHD power generating plant are being studied.

The Bureau's program is aimed at providing endurance and property data on materials, obtaining criteria for MHD system design, and assisting in developing specifications and test methods for containment materials. With this knowledge, planners of MHD systems will be able to predict how certain combinations of materials will behave under given conditions.

With MHD, electricity is produced by passing a conducting stream of hot, ionized gas through a transverse magnetic field. In open-cycle MHD, combustion gas from the burning of fossil fuels serves as the conductor, and electrodes placed in the gas stream generate direct current at high voltages.

The MHD technique virtually eliminates the sulfur dioxide pollution and considerably reduces nitrogen oxide emissions produced by conventional fossil-fuel power plants. Development of this system could result in a greater efficiency than present fossil-fuel generating plants.

However, the combination of seed material (alkali salts added to make the gas more conductive) and high temperature (2000-2400 °C) produces an extremely hostile environment. Typically, the parts of the system exposed to the gaseous stream must resist corrosion through oxidation, erosion, and alkali attack, and must remain unaffected by thermal shock and extreme temperatures.

MATERIALS CHARACTERIZATION

Initially, Bureau researchers are concentrating on defining the behavior characteristics of materials that may be used in MHD, and in characterizing the coal slag that will be flowing through the system.

Coal slag. In order for the reactions of the construction, insulating, and conductive materials to be completely understood, the composition of the coal slag and flyash must be known. This is being determined by chemical analysis, x-ray diffraction, petrographic examination, differential thermal analysis, and Mössbauer spectroscopy. A factor complicating these analyses is that the mineral content of the coal varies according to the geographical location from which it was mined.

Synthetic slags are also being prepared to determine the effect of each component on the melting, viscosity, stability, and electrical conductivity characteristics.

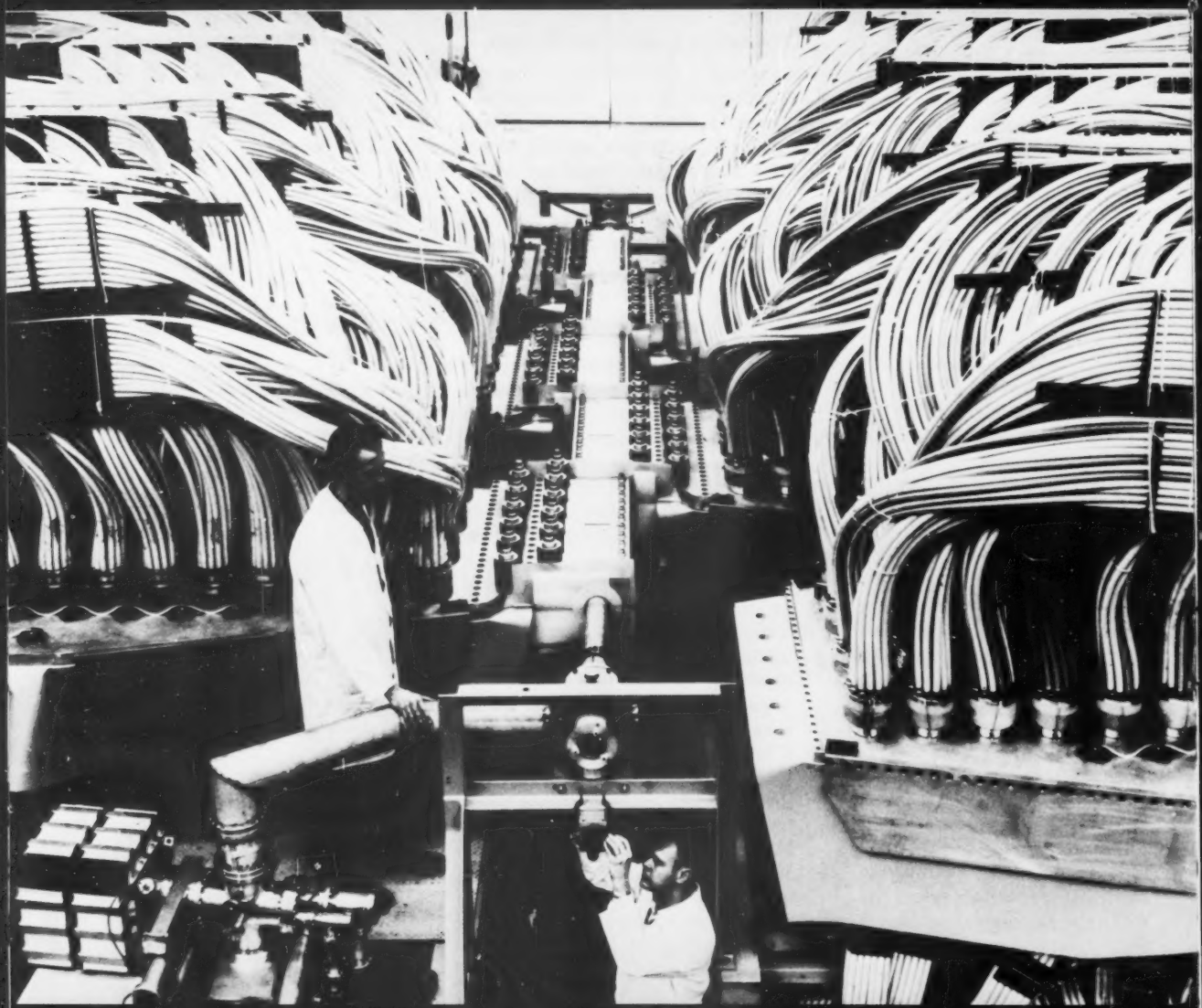
Vaporization. New data are being collected that, when used with existing knowledge, can be used to predict and aid in understanding the transport of slag components from a coal-fired combustor to the MHD unit and the transport of construction materials through formation of gaseous species. The main objective is to obtain new information on important gaseous ternary species; especially metal hydroxides, which might be formed by reaction of water with slag or construction materials. In addition, data on the vapor pressure of solutions are being collected so the minimum temperature to avoid liquid formation can be determined.

Viscosity. To control the viscosity of the slag it is necessary to control the wall temperatures and to know the viscosity-temperature relationship for slags of different compositions. To accomplish this, Bureau scientists are adapting a viscometer to make reliable viscosity determinations of a slag up to 1500 °C in selected environments. Both natural and synthetic slags are being studied.

Electrical conductivity. Measurements as a function of temperature and pressure are being made on real and synthetic slags of varying composition. A furnace has been constructed in which conductivity measurements can be made as a function of atmospheric pressure and temperature up to 1800 °C. It is planned to determine the conductivity of slags in conditions up to 2400 °C. The conductivity of slags will also be measured in inert gases containing known amounts of oxygen. This should give information on the effect of oxygen partial pressures on conductivity.

Seed materials. The addition of alkali salts to the MHD system is necessary to increase gas phase conductivity. Knowledge of the chemistry and phase relations of the pure seed materials is required before investigations can be made of the more complex insulator-electrode-slag-seed interactions. The phase relations of the more common alkali salts are being studied using various techniques, including DTA and high temperature x-ray diffraction.

HYDROGEN ARC RADIOMETRY APPLIED TO FUSION EFFORT



A major controlled thermonuclear reaction experimental device, the Linear Scyllac at the Los Alamos Scientific Laboratory. Photo courtesy U.S. Atomic Energy Commission.

■ A Bureau-developed radiation standard could have significant application in the production of energy by controlled nuclear fusion.[1,2]

The standard is a hydrogen arc providing a known, stable and stationary source of radiation in the vacuum ultraviolet (vuv) region. Since most of the radiation produced by fusion plasmas is in this region, the standard will permit fusion scientists to relate their vuv radiation measurements to such important plasma characteristics as temperature and electron density with unprecedented accuracy. The standard will also be useful to space astronomers making observations on the vuv spectra of the sun and other stars.

RADIATION STANDARD SOURCE

The radiation standard source is a wall-stabilized electrical arc, 5 centimeters long, operating in pure hydrogen. The arc is struck between a set of four tungsten cathodes and four tungsten anodes and is constricted by a stack of 24 water-cooled copper discs having a 2 mm hole through the center. The discharge reaches equilibrium temperatures of about 24,000 K, more than four times the temperature of the sun's surface, and constitutes one of the hottest continuous sources of radiation in existence. The radiating properties are nearly uniform at these high temperatures for a 0.3 mm diameter cylindrical volume centered on the arc axis. Therefore the basic intensity measurements used in a calibration are done with the arc in the "end-on" configuration, that is the radiation emitted from a very narrow cone along the arc axis is observed through the electrodes.

The standard was developed by Drs. William R. Ott, Patrick Fieffe-Prevost (a visiting scientist from the Bureau National de Metrologie, Paris, France), Kurt Behringer (a visting scientist from the Technische Universität in Munich, Germany), and Wolfgang L. Wiese. They recently demonstrated that the continuum radiation intensity from a 20,000 °C temperature plasma, which is exactly calculable for the conditions encountered in a conventional dc wall-stabilized arc, can be reliably produced and analyzed.

The basic reason why the light intensity can be put on an absolute scale is because the hydrogen plasma at such high temperatures, is reduced to the most elementary plasma and is the only one for which an essentially exact theory is available, an equilibrated mixture of electrons and protons.

Calibrations using the hydrogen arc method have been compared with other less versatile and more specialized ultraviolet calibration methods and are in agreement to within 10 percent in the wavelength region 130 nm to 360 nm. Ultimately the technique is expected to be useful down to about 50 nm.

CALIBRATION METHOD

Several *transfer* or *secondary standards* have already been calibrated in the range 165 nm to 300 nm using the hydrogen arc as the primary standard. Such service is available by special request. To calibrate a secondary lamp or a radiating plasma against the hydrogen arc the two sources are set up so that the radiation from both can pass through the same optical-spectrometric arrangement, thereby eliminating all geometric and other specific factors of the instrumentation. By recording the response of the system to the standard hydrogen arc spectral radiance, then flipping a mirror to direct the hydrogen arc beam away and allowing the test light beam to enter the same measurement device, the test plasma radiation can be calibrated against the measured hydrogen arc photoelectric spectrum.

SIGNIFICANCE OF NEWLY DEVELOPED STANDARD

The United States thermonuclear fusion program has been stimulated by the ever increasing energy needs of our industrial society and by the simultaneous gradual depletion of conventional fossil fuels. It is generally agreed that the most economical and pollution-free long range answer to the energy problem is controlled thermonuclear fusion, the harnessing of energy obtained by fusion of various hydrogen isotopes. Scientists and engineers are trying to achieve this goal by heating the isotopes to extremely high temperatures in large plasma confinement machines.

If the vacuum ultraviolet light intensities emitted from the fusion plasmas are accurately calibrated, these spectroscopic measurements can be related to such important diagnostics as plasma temperature and electron density determinations as well as the effect of vacuum system impurities and those impurities which are vaporized off the chamber walls during a fusion reaction. By making use of NBS calibration services and facilities, such calibrations should soon become routine as well as accurate, thus reducing the time spent on developing other more involved and expensive methods and also enabling more definitive experiments which may even lead to an efficient (break-even) fusion machine.

[1] Ott, W. R., Fieffe-Prevost, P.,* and Wiese, W. L., VUV radiometry with hydrogen arcs, to be published in Applied Optics, Aug. 1973.

[2] Ott, W. R. and Behringer, K., Absolute vuv radiometry with hydrogen arcs—comparisons with blackbody calibrations. To be presented at XI Int'l. Conf. on Phen. in Ionized Gases, Prague, Czechoslovakia, Sept. 10, 1973.

RESEARCH ASSOCIATE PROGRAMS CONTINUE ACTIVE

Seventeen Research Associate Programs are currently active at the Bureau with 54 individual Research Associates participating under the sponsorship of industrial, trade, and professional organizations.

Dr. Richard W. Roberts, Director, right, presents a Certificate of Appreciation to Dr. Kenneth C. Lyon upon completion of Dr. Lyon's Research Associate Program, which was sponsored by the Glass Container Manufacturers Institute. The objective of the program was to devise a method for predicting viscosities of container glasses as a function of temperature and composition. The citation on Dr. Lyon's certificate reads: "In recognition of his contribution to glass science and technology through the accurate prediction of glass-forming properties."

Members of the Glass Container Manufacturers Institute and NBS staff discuss the GCMI-sponsored glass properties Research Associate Program at its conclusion. Occasion for the meeting was the presentation of a Certificate of Appreciation to the Research Associate, Dr. Kenneth C. Lyon, far left, by Dr. Richard W. Roberts, Director, second from right. Others in the picture, left to right, are Mr. P. R. de Bruyn, NBS Industrial Liaison Officer; Dr. John G. Turk, GCMI Vice President—Technical; and Dr. Wolfgang Haller, Chief, Inorganic Glass Section. Dr. Haller served as NBS supervisor for the program.

The Research Associate Program has a history of over 50 years of productive interaction between industry and the Bureau. Since 1965 alone, 59 organizations (24 trade and professional groups, 29 companies, 4 governmental organizations, a hospital, and a university) have sponsored 68 different Research Associate Programs at the Bureau.

A Research Associate, selected from the staff of the sponsoring organization, normally spends 1 or 2 years (or longer) at NBS working toward the solution of a specific problem of mutual interest to his organization; the industry, trade or profession represented; the Bureau; and thus to the public. The highly skilled professional staff, the advanced measurement technology, and the broad range of activity and information at NBS are available to guide and assist the Research Associate in his work. He, in turn, brings knowledge of both the latest advances and current problems of private industry, thereby enabling the Bureau to program its own efforts more effectively and increase its responsiveness to public and industrial needs.

The NBS Office of the Associate Director for Professional and Academic Liaison is the focal point for the Research Associate Program and for liaison between industry and the Bureau. Any industrial organization, trade or professional association, or other potential sponsor wishing further information on the Program may write to or call Mr. P. R. de Bruyn, Industrial Liaison Officer, Room A402, Administration Building, National Bureau of Standards, Washington, D.C. 20234, Telephone 301/921-3591.

Dr. Richard W. Roberts, Director of the National Bureau of Standards, U.S. Department of Commerce, addressed the 1973 Spring Meeting of the American Physical Society on April 23. Following is an abstract of Dr. Roberts' speech:

IMPACT OF FEDERAL SCIENCE ON THE NATIONAL ECONOMY (ABSTRACT)

Through the history of the United States, science and technology have played a giant role in the development of the economy and of our society. The agricultural revolution and the industrial revolution fed on the developments in the laboratory. Today's leadership in high-technology products like computers, electronics, and chemicals resulted from developments beginning with World Wars I and II and the space chase of the 1960's.

The government has good reason to support science. First, as a major consumer, the government must stimulate or develop new products or technologies to meet its own needs. It also has a traditional role of doing for the people what they cannot do for themselves. This has been especially true in the case of support to graduate education to which the nation has dedicated a large amount of support over the years. It is also true in the case of supplying the measurement base (standards) against which science, technology, and commerce may evaluate their products and performance.

Today, America faces new economic challenges from abroad. We have, for the first time this century, a negative trade balance. Yet, we have technical and trade superiority in the areas of agriculture and high-technology products where science and technology have had a major impact. It is crucial that our lead in these areas be maintained and even increased to balance against our imports of low-technology goods. Since new technology accounts for nearly two-thirds of the growth in labor productivity, it is also important that we turn our attention toward enhancing U.S. productivity in all areas, especially in the service sector.

Scientists and engineers have the opportunity to apply their knowledge to the solution of major national problems. This time, as articulated by the President, it is helping America retain or regain its position of world leadership in trade. American industry had traditionally been concerned with the economics of science and technology. While much important new knowledge has come from the industrial research laboratory, the scientists there have asked the question, "if I am successful, so what?" The National Bureau of Standards has also produced some fine research even while helping American industry apply scientific knowledge.

Now the government is looking for new ways to ensure that the fruits of scientific research and technology can be brought to the marketplace. One of these areas is in the area of energy generation and conservation where service and technology can make a major impact on a national social-economic problem. Another is the new NBS technology incentives program which is aimed at identifying and testing the barriers which may exist to innovation or application of technology in American industry.

Obviously, the new economic concerns will require some new thinking on the part of American scientists. What may be necessary as new projects and new programs are developed, is the consideration of the economic impact of these programs. It is important that science and technology help solve, rather than intensify our social and economic malfunctions.

Federal priorities and science policy are changing to reflect economic concerns. Using science to solve current problems, and to promote economic growth, is a role many may feel uncomfortable with. Assessing the economic impact of our research may be difficult, but is possible. But, ready or not, like it or not, everyone is in it together. Cooperation at every level—Federal, state, local, industry, university, individual—is essential if we are to make optimum progress.

Basic research is certainly not dead. It's even more important than ever. Nor, over the years, has American science callously ignored the problems of American society. It's responded quickly to national needs.

Scientific research can still be basic or speculative and long range, yet at the same time relevant. A new era is upon us, one in which science will be increasingly looked to for the solution of our social and economic ills. This is a challenge that all can and must respond to. Government should reflect national goals and priorities. The scientific community must assess and articulate its capabilities for meeting these goals. And the government must support those programs which contribute to their attainment.

OPTICAL RADIATION NEWS

Optical Radiation News (ORN) is intended to serve as a means of communication among workers in industry, universities, and government agencies involved in radiometry and photometry. ORN will focus on developments in the laboratory, in the published literature, and at the council table, which are of interest to its readers.

HAS THE TIME COME TO REDEFINE THE CANDELA?

At the Optical Society of America meeting last March in Denver, the Radiometry and Photometry Technical Group held a "Reexamination of the Photometric Unit System." A panel led by Dr. Richard Becherer of Polaroid reviewed the following aspects: *The Rationale for the Present System* (Louis Barbrow, NBS); *Technical Problems with the Present System* (Edward Zalewski, NBS); *A Proposed Redefinition* (William Blevin, NSL, Australia); and *Consequences for Colorimetry* (Gunter Wyszecki, NRC, Canada). The meeting was held in cooperation with Technical Committee 1.2 of the Commission Internationale de l'Eclairage (CIE), of which Becherer is Technical Projects Coordinator. A status report will be prepared by Michael Zinchuk of Polaroid for presentation to the international CIE Technical Committee 1.2 this summer.

This review is of considerable interest now, not only because of growing commercial concern for intercomparability between radiometry and photometry, but more specifically because of the CIE meeting this summer. In the past, the CIE has led activity in addressing various aspects of practical photometry of international concern. Recently the focus provided by the Council for Optical Radiation Measurement (CORM) in addressing technical problems concerning American photometry and radiometry has led to considerable interest and widespread CORM comment on such a reexamination.

BECHERER

Becherer started the discussion by noting that the basic problem was one of growth in the electro-optics industry. He pointed out that the ties between radiometry and photometry were increasing and, in particular, that new types of light sources required both types of measurement. He also identified a general trend toward spectral rather than broad band power measurements.

According to Becherer, the U.S. Technical Committee is considering making a recommendation to the international CIE committee for a redefinition. If the international Technical Committee were to share the enthusiasm of the American Committee for such a redefinition it would presumably make a recommendation to the Comité Consultatif de Photométrie et Radiométrie (Consultative Committee for Photometry and Radiometry). It in turn would make a recommendation to the Comité Internationale des Poids et Mesures (The International Committee on Weights and Measures), which finally would make a recommendation to the Conférence Générale des Poids et Mesures (The General Conference on Weights and Measures). The Conférence Générale would officially redefine the base photometric unit. Becherer also pointed out that 18 years elapsed between the adoption in principle of the present definition of the candela and its final adoption in practice in 1948. What is presently being considered, then, is an adoption *in principle* of a new definition of the primary photometric unit.

BARBROW

Barbrow focused on three questions. First, he noted that the present definition in terms of the luminous intensity of a unit area of a platinum blackbody is applicable to visual measurements not only at relatively high light levels (photopic conditions) but also at low light levels (scotopic conditions) and intermediate levels (mesopic conditions). He noted that the concept of equivalent luminance also deserved special emphasis, since it is tied directly to the present definition of the candela.

Barbrow's second point was that practicality ought to be the predominant consideration, a view shared by all of the other speakers during the subsequent discussion. He mentioned that practicality dictated preservation of an SI base unit of light on two scores: (1) such a unit certainly is needed as much in the field of light and vision as is the mole in the field of chemistry, and (2) there is no justification to purge the light unit in order to maintain a nonexistent limitation on the number of SI base units.

And finally, he reiterated that the present definition was applicable to

visual measurements at all levels, particularly to equivalent luminance. He concluded by stating that radiometrically based redefinitions would sacrifice the breadth of applicability of the present system. He emphasized that the SI unit of light should satisfy the needs of all disciplines related to light and vision.

ZALEWSKI

Zalewski started by differentiating between early photometry, which he identified as psychophysical photometry, and current photometry, which he identified as physical photometry. His emphasis, however, was on the concept of intensity, particularly as a primary *quantity*, rather than on the present definition of the candela as a *unit* based on the platinum point blackbody. He identified two major issues: First, that unavoidable systematic errors occur in the realization and transfer of an intensity standard; and second, that there are ambiguities in the present CIE definition of intensity. He pointed out that this was not merely of academic interest, but is a substantial hurdle to be overcome in the laboratory realization of a scale of luminous intensity.

Three specific systematic problems were identified. In the first place, an extrapolation to infinity is involved, and the fitting must be applied to a curve of unspecified form. Secondly, the point of origin of the coordinate system involved is not precisely known for real sources. And thirdly, the statistical weights to be employed in any curve-fitting process involve a subjective decision. Although these problems can be avoided, at least in principle, by measuring illuminance rather than photometric intensity, Zalewski noted that two immediate problems preclude such a practical replacement. First, the candela has been defined as an SI Base Unit and the national laboratories therefore feel an obligation to maintain this unit. Secondly, he noted that the present definition of the candela, as modified in 1967, is in terms of the luminous intensity of a small but definite area of a platinum blackbody and not related to luminance in any conceptually simple way.

Zalewski started by differentiatmendations for consideration by the Technical Group: (1) The CIE intensity definition should be modified; (2) The relationship between illuminance and distance should be referred to as "the inverse square approximation," not the "inverse square law"; (3) The candela should be eliminated as an SI Base Unit; (4) An illuminance scale rather than a luminous intensity scale should be maintained by the national laboratories; and (5) Photometric output of a blackbody should be described in terms of luminance [units of $(\text{lumens}) \times (\text{area})^{-1} \times (\text{solid angle})^{-1}$].

BLEVIN

Blevin began by noting that he had worked both in radiometry and in photometry, a relatively unusual background. He noted the mixture in early photometry of objective and subjective measurements, that is, those made with physical detectors and those made visually. He observed that, for practical purposes, photometry was now largely an applied branch of radiometry. This change in emphasis has been made possible by the acceptance of agreed eye response functions $V(\lambda)$ (*photopic*) and $V^1(\lambda)$ (*scotopic*) and of the present definition of the candela. The present definition, he said, serves in reality to enable values to be computed for the constants K_m and K_m^1, which relate the lumen to the watt. Blevin considers, therefore, that a redefinition of the photometric units explicitly in terms of radiometric ones would be in reality an *amendment* and not a substantial *redefinition*.

Focusing also on the necessity for practicality in the unit system, he defined two new factors that have arisen since the 1930's and the genesis of the present definition: (a) the widespread use of sources with different spectral distributions; and (b) the development of more precise detector techniques that, with a redefinition, would provide a more certain realization of the base unit. He considers that radiometric and spectroradiometric techniques, placed at a disadvantage by the present definition, would offer "greater precision, greater reproducibility, and greater convenience."

The present confusion rests largely upon lack of general agreement on values adopted for the freezing point of platinum. Values between 2045 K and 2040.75 K are now being used. The agreement in the early platinum experiments is largely fortuitous due to cancellation of systematic errors in the various experiments. Blevin proposed redefinition of a primary photometric unit, either the candela or the lumen, in terms of the corresponding radiometric unit at a given wavelength. Adoption of the specific wavelength where $K(\lambda)$ and $K^1(\lambda)$ curves intersect (approximately 555 nm) would enable a single definition to apply both to photopic and to scotopic photometry. Several advantages were noted: first, the employment of superior new methods as they become available; second, the exactness of cross computations between radiometry and photometry; and third, the clarification of the nature of the measurements to those people inexperienced in photometry.

WYSZECKI

Finally, Wyszecki pointed out that, strictly speaking, there were no consequences for colorimetry in a redefinition. He identified the field of colorimetry as that which predicts which visual stimuli of differing spectral distribution will have the same color. The more general

and more important problem of dealing quantitatively with color differences has not yet been satisfactorily addressed by colorimetry, according to Wyszecki. Such an expansion is its present task.

GENERAL DISCUSSION

A lively general discussion followed these invited reviews. The primary concern of all participants was the practical utility of the unit system, as the essential touchstone for consideration in a redefinition. Several distinct emphases apparently exist, however, concerning the problems for which practical utility is to be optimized. As long as the central purpose of photometric measurements was the prediction of relative brightness, while at the same time the techniques being employed in the system were visual techniques, measurement problems were obscured. Measurement disagreements are now more obvious because the techniques being used in commerce are relatively precise physical ones, while the ultimate purpose of the unit system, to predict visual brightness, has not in fact changed. It was widely recognized that the present photometric unit system did not permit prediction of visual brightness within a factor of 2 or 3, under unfavorable circumstances, while commercial measurement can be made physically much more precisely. It is also widely recognized that radiometric data are required in accurate and precise vision science. Should then the admittedly grossly simplified photometric unit system be more tightly coupled at this point to a radiometric foundation? Or should it be retained unchanged precisely because of the common reference point it offers all measurements, whatever the condition of *visual* adaptation.

In the end there seemed to be very broad, although not complete, agreement that effort ought to be pushed in two directions. On the one hand, the physical measurement system ought to be made as precise as practicable. On the other hand, an effort ought to be made to design a more comprehensive photometric system that would achieve far greater success in predicting brightness than can the present system. But nobody foresaw a photometric system that would predict brightness adequately in all cases. There seemed to be broad feeling that, with a relatively modest increase in complexity of the system, one could achieve far greater success in the prediction of visual brightness. A number of participants would prefer to put the emphasis on physical measurements and an increase in their precision. Others would prefer to put the emphasis on the design of a more complex system for enabling one to predict with much greater success visual brightness from detailed spectral information. A redefinition of the photometric unit system explicitly coupling it to the radiometric system would constitute a conceptually minor, but important practical, step to the former group; and a small, but useful, step to the latter group.

BASIC QUESTIONS

In a serious consideration of a redefinition of the photometric unit system in terms of radiometric units there are three questions to be addressed. First, should a photometric unit be retained as a Base Unit of the SI? Second, should the *platinum point* remain as the starting point of the photometric unit system? And third, should the quantity, *intensity*, provide the basis of the photometric unit system.

The first question was widely recognized to be beyond the scope of a practical discussion. This question is primarily philosophical in nature. Since the focus of the discussion was on the practical aspects of a conversion, this question was not discussed at any length.

With regard to the second question, the desirability of retaining platinum in the definition of the unit system, there is strong evidence that radiometry built either around the gold point or around electrically calibrated radiometers offers precision and accuracy at least comparable, and probably superior, to that obtainable with platinum blackbodies. A redefinition would free laboratories to use the most precise method of realization that is most tightly coupled with the rest of SI. Such a choice is currently available for the derived units such as the watt. The question of mesopic and scotopic photometry could be handled in one of several ways outlined by Blevin. Although his suggestions require some additional explicit agreement in the case of mesopic photometry, they probably offer vision scientists as firm a base upon which to base a prediction of brightness as does the platinum point definition.

And finally, with regard to the question of intensity, the technical problems outlined by Zalewski must be balanced against other considerations noted by Blevin. No reluctance was expressed on the part of those present to a proposal for building the photometric unit system on the lumen/watt quotient, rather than retaining the foundation in intensity. Although it was recognized that such a proposal is not new, changes associated with the field both practically and conceptually seem to dictate a new serious proposal and a formal reevaluation of alternatives at this time. There will not be full satisfaction in the long run with a photometric unit system that does not provide more reliable prediction of brightness than the present one. A redefinition of the photometric unit system in terms of radiometric units was seen as a small but useful step in this direction.

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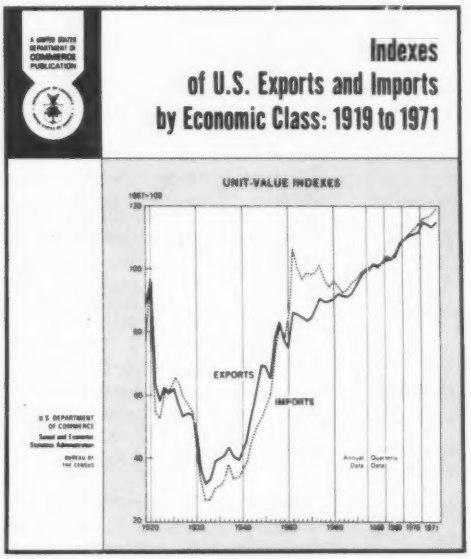

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